Space Syntax,

Backgraound and Developement

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Space syntax is a set of measures for space configuration that have been shown to correlate well with how people move through and use building and urban spaces, in this paper we describe the concept of space syntax as an analytical tool used to examine the configuration of different layout patterns into a numerical and mathematical measurements, at the end of the paper, a case study area from Brno is chosen to explain how different configurational properties of space layout could affect the movement of people within it.

The concept of space syntax:

Over the past two decades, space syntax has been proposed as a new computational language, was first developed by Hillier and Hanson (1984),. for representing and measuring the pattern properties of open space in the built environment. The notion of syntax, refers to relationships between different spaces, or interactions between space and society. These principles support the belief that spatial layout or structure has great impact on human social activities. (Jiang & Claramunt, 2002).

Hillier showed that by translating the spatial properties of the space into a mathematical based measurements and then by analyzing different kind of spaces or city patterns it will be possible to determine many aspects of which the spatial layout structure affects the human social activities (Hillier & Vaughan, 2007), he called the resulting form of numerical representation of space layout, the spatial configuration, which refers to the simultaneously existing relations amongst the parts or the interrelations between the many spaces that make up the spatial layout of a building or a city.

Typical applications of space syntax include pedestrian modeling, criminal mapping, and way-finding processes in complex built. All these investigations tend to be based on the assumption that spatial patterns, or structures, have a great impact on human activities and behaviours in urban environments. (Jiang & Claramunt, 2002)

Axial line-based space syntax:

Axial line is the earliest approach of the space syntax. Developed by Hillier and Hanson (1984) to represent and measure the pattern properties of open space in the built environment (Kim & Penn). The axial map of an area is drawn on the basis of open-space structure in a plan, it consists of the least set of straight lines of sights that pass through all the open spaces in an urban area (Hillier, 1996). Figure 1 shows this procedure: (a) the open space structure and (b) an axial map.

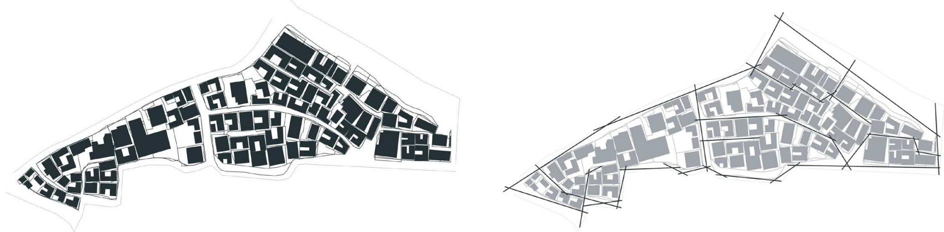


Figure 1 (a) the spatial structure of open space, (b) the axial representation.

This map is then translated into a graph in which a line is represented as a node and intersections between lines are shown as links between nodes. Measures of the graph are made that can then be assigned back as variables associated with the location of each line in the original map (Penn & Turner, 2002).

In terms of how each line intersects other lines, various morphological parameters can be derived for the analysis of an urban structure. These parameters include the connectivity, mean depth, local and global integration.

- The Connectivity of an axial line measures the number of lines that directly intersect that given axial line.
- The depth of an axial line is defined by the number of lines distant by a given number of steps to that axial line (Jiang & Claramunt, 2002).

- The mean depth is the average depth from one element to all other elements in the system, and essentially reflects an enumeration of all possible sequences through the building or urban environment.., and thus might be considered to give an idea of what the general experience of a space might be from each location (Turner, 2003).
- The `integration' of every location, is a measure of how deep each location is to all others. A well integrated location is that, you do not have to turn often to get from the location to any other in the system. Local integration considers the connectivity with the lines up to a few steps away. Global integration considers the connectivity with the lines up to all steps away (Turner, 2004).

The graph measures obtained from these axial maps have been applied to solving various problems in urban systems. For example the effect of configuration of space on pedestrian movement in urban environment (Hillier, 1996) and building environment (Batty, et al. 1998).

Isovist-based space syntax:

The second approach of syntactic measurements is based on the Isovist space. The concept of the Isovist began with Benedikt (1979) who introduced a set of analytic measurements of isovist properties to be applied to achieve quantitative descriptions of spatial environments. He starts by considering the volume visible from a location and then simplifies this representation by taking a horizontal slice through the `isovist polyhedron'. The resulting isovists are always single polygons without holes, as shown in (figure 2).

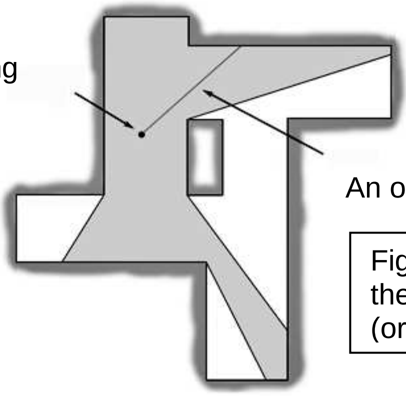


Figure (2) an isovist polygon, incorporating the visible area from a generating location (or convergence location of the optic rays)

Consequently, Benedikt considers geometric properties of isovists, such as area and perimeter. Thus he begins to quantify space, or what our perception of space might be, and the potential for its use. Benedikt notes that, in order to quantify a whole configuration, more than a single isovist is required and he suggests that the way in which we experience a space, and how we use it, is related to the interplay of isovists.

However, applications of the isovist in architectural analysis have been limited to a small number of studies. And the reason was that the geometric formulation of isovist measures local properties of space, and the visual relationship between the current location and the whole spatial environment is missed, including the fact that the internal visual relationships between locations within the isovist are ignored (Turner et al. 2001).

To overcome these limitations of original idea of Isovists which basically describe local physical properties of spaces with respect to certain standpoints. Turner et al, (2001) developed a new technique - in which a set of isovists can be drawn at any location in space, then a graph of lines of sight connections can be constructed by using the visual relationships between these isovists- called visibility graph analysis.

Visibility Graph Analysis:

Turner et al. (2001) developed the methodology of visibility graph analysis

Which considers regional or global properties of a whole environment by computing the intervisibility of positions regularly distributed over the whole environment (Wiener & Franz, 2004).

The most obvious approach is to generate isovists throughout a spatial system at points defined by some sort of grid or regular lattice. One meter resolution for the grid, for example,(if we are mapping only space that is related to human perception of an environment). After selecting a set of generating locations, which relationships between different isovists in an environment should be included in an isovist graph, the most obvious relationship to consider occurs where two isovist polygons intersect with one another. Arguably, a stronger relationship between two isovists exists where they intersect and their generating locations are mutually visible. In order to determine this relationship, a graph can be made with physical locations as vertices, and form edge connections between pairs of locations if they are mutually visible. This is a visibility graph of the system. As, by definition, an isovist from a given generating location contains all the locations visible from it, this is referred to as first-order isovist graph. by taking a visibility `step' from one isovist-generating location to an intervening location, and then a `step' onto the next isovist-generating location. Hence this is referred to as a second-order visibility relationship (figure 3). This new technique of Isovist integration is currently being tested on a number of urban areas (Turner et al. 2001).

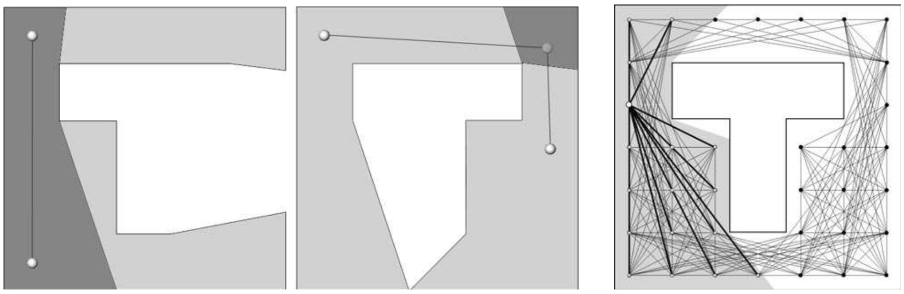


Figure 3 (a) First - order and (b) second-order visibility relationships between isovists. In the first-order graph, the two points are linked directly rather than through an intermediate point, (c) shows an example graph made from thirty-six point locations.

Figure (4) shows the same area of the integration map for the whole of London. A visual inspection shows that there is a great degree of similarity between the two analyses. The isovist integration map, however, shows a considerably increased level of fine scale detail, especially in the changes in integration value along the length of streets, the increase of integration at street intersections and in variations across the body of open spaces. This is possible since the integration value is calculated for a node located at a single point in space (Turner et al. 2001).

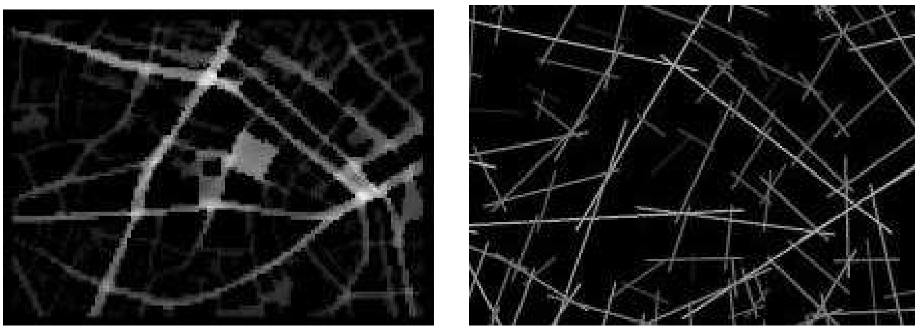
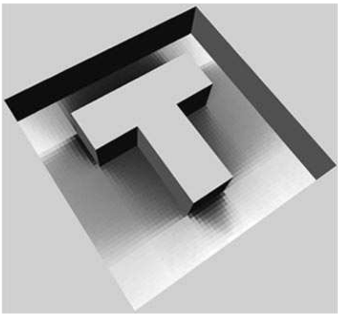
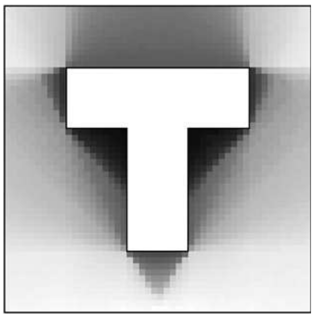


Figure 4(a) shows isovist integration in the area of the City of London around the Baltic House site. The map is composed of about 10000 nodes on a 6-metre grid. (b) the axial line based integration for the same area.

Figure (5) shows the mean shortest path length (*) mapped for a simple spatial configuration, for a graph with 2000 vertices. The lower (mean shortest path length) values are colored white in the figure, whereas higher (mean shortest path length) values are black.

(*) Mean shortest path length (mean depth): The shortest path between two vertices in a graph is the least number of edges that need to be traversed to get from one vertex to the other. The mean shortest path length for a vertex is simply the average of the shortest path lengths from that vertex to every other vertex in the system, and so represents an average of the number of turns (plus one) required for any journey within the system.





Isovist Integration in building and urban space:

Visibility analysis provides an attractive way to investigate and translate the environment system into a mathematical statement which can be applied to the experience of urban and building environments. For example, to determine what the perceptual qualities of a building might be, to categorize different urban types, or to examine how people can move or interact within the visible space (Turner, 2003).

Substantial progress has been made in the validation of the isovist integration analysis at the building interior scale, to predict pedestrian movement behavior, an analysis was made of the Tate Gallery in London by Hillier and his colleagues. Isovist integration was applied to a model of the building, Figure (6) shows on the right traces of 100 people entering the Tate Britain gallery in London and moving about for ten minutes. On the left is a visual integration analysis of all the visual fields from every point in the Tate plan. The nodes are colored according to a grayscale, ranging from black (least integrated) to white (most integrated).

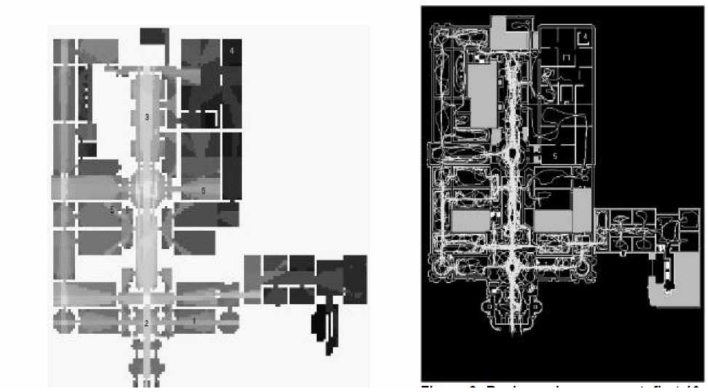


Figure 6 First ten minute movement traces (left), and visual integration analysis (right) of Tate Britain

It is easy to see that the movement and space patterns resemble each other as patterns quite closely. This can be checked statistically. By correlating the visual integration values with observed movement, it turns out that about 68% of the differences in movement rates in rooms can be accounted for by the visual field structure, implying that people are using the space structure of the Gallery, rather than, say, the attractive powers of particular exhibits, to guide them around the gallery (Batty, et al. 1998).

Another example of how to apply the space syntax means to investigate the effect of urban pattern on functioning. Hillier took five separate areas of London, with observation of pedestrian and vehicular flows in around100 street segments in each area, and correlated the flows with different Configurational measures for each street, to investigate if more integration means more movement (Hillier & Vaughan, 2007).

He found striking results. The degree of correlation between vehicular flows and radius 3 integration was over 0.7, and for pedestrian about 0.6 which means 70% of the differences in vehicular movement flows, and 60% of pedestrian are due to the pattern of the street network.

Case Study:

In this paper, two different areas in Brno city were examined, first example, (figure 7), the area where Videska street crosses Svratka river, shows visually different numerical values for the layout properties in term of integration measurements, using red color for the most integrated parts, through blue for the least, it is obvious from different parts across Videnska street that are marked with the red color, that this is the most integrated axis, contrarily, the other axis along Svratka river, seems to be less integrated, this imply a suggestion that the Videska street is the focal part for the pedestrial and vehicular movement more tha any other parts within this area......

Figure (7 the area where Videska street crosses Svratka river, the visually numerical representation of the layout properties, shows that the area within Videska street marked with the red color is the most integrated parts, hence it supports the suggestion for being the most interested part for pedestrian movement

Second example figure (8) is the area of and around the freedom square, the aim is to examine how different integrated parts of space layout are related to the pedestrian movement. Onsite observations for the pedestrian movement were carried out during the working days from 6th to 10th of April 2009. the observations consist of counting the pedestrian traffic in 66 points within this area, the traffic calculations is being observed for 10 minutes in each point.

After checking statically the integration values and the pedestrian movement in all these points, the result was a considerable correlation value of $R^2 = 0.698$, which reflects the effect of the visual layout properties on a large amount of the differences in pedestrian movement rates within this area......

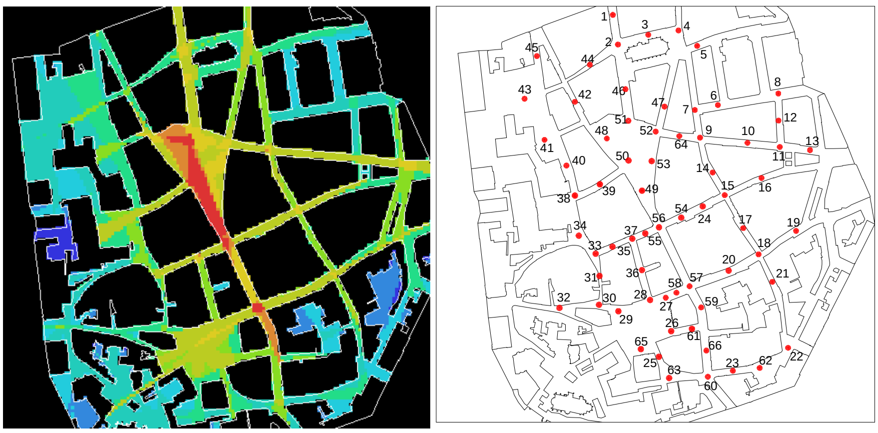


Figure 8 (left) visual integration analysis, (right) the locations of the pedestrian movement observations, Freedom Square, Brno.

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Appendix:

The table shows the values of 10 minutes pedestrian observations and the Parallel visual integration for different points within the area of Freedom Square.

Ref Number	Visual Integration	Pedestrian		Ref Number	Visual Integration	Pedestrian		Ref Number	Visual Integration	Pedestrian
1	4.4	580		23	3.3	254		45	3.02	116
2	4.76	264		24	4.27	220		46	4.45	340
3	3.51	70		25	4.03	200		47	4.15	110
4	4.62	220		26	4.1	100		48	5.19	400
5	3.39	90		27	4.44	326		49	5.71	860
6	2.95	50		28	4.36	300		50	5.87	802
7	3.88	138		29	4.41	280		51	4.77	430
8	3.43	64		30	3.82	220		52	4.74	427
9	4.69	500		31	3.49	74		53	4.69	432
10	4.37	284		32	3.55	100		54	4.26	261
11	4.45	320		33	4.55	202		55	4.27	300
12	3.21	60		34	3.83	180		56	5.58	638
13	4.37	380		35	4.27	150		57	5.6	721
14	4.2	240		36	3.92	130		58	4.41	370
15	4.74	360		37	4.27	160		59	5.1	540
16	4.47	150		38	4.49	225		60	4.19	638
17	4.15	324		39	4.32	150		61	3.97	640
18	4.73	436		40	3.66	152		62	3.3	321
19	3.54	152		41	3.91	192		63	3.54	180
20	4.4	284		42	3.59	600		64	4.39	338
21	4	94		43	3.79	220		65	4.09	159
22	3.31	490		44	3.41	86		66	3.98	500